Numerical study on the performance characteristics of a liquid injection cycle

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INTRODUCTION
Background of research

- Severe environmental conditions
  - Increasing compression ratio
  - Rising discharge refrigerant temperature
  - Reduce heating and cooling performance
  - Oil carbonization and malfunction
  - Performance and reliability

- Vapor injection system
  - Reduce compressor power consumption
  - Increasing heating and cooling performance
  - Flash tank or Internal heat exchanger is needed → Rising production costs and failure
  - Ensure the reliability at hot temperature cooling is difficult

Ensure the reliability in hot temperature cooling mode using liquid injection technique
Purpose of this research

- Development of a simulation model for the heat pump cycle with liquid injection technique.
- Validation of the simulation model with experimental data.
- Analysis of liquid injection cycle using the simulation model
- Analysis on the performance characteristics with the design conditions of injection port
SIMULATION MODEL
Flowchart of simulation model
Flowchart of injection pressure

1. Start
   - Input: Compressor, Port specification
   - Calculation: Opening ratio, Internal pressure of compressor during injection process
   - Adjust Intermediate Pressure
     - If M_{eev} = M_{Ori}, Yes: Stop
     - If No, Simulate EEV
     - Simulate Orifice
2. High Pressure
   - EEV correlation (Park et al.)
3. Compressing Pressure
   - Intermediate Pressure
   - Orifice correlation (Choi et al.)
Opening ratio 1

percentage of injection port is open without being blocked by the roller

Opening Ratio 1 \[ R_{\text{open1}} = \frac{360 - 2\theta}{360} \]

Heron's Formula
\[ \frac{1}{2} * a * b * \sin(\theta) = \sqrt{s(s-a)(s-b)(s-c)} \]

\[ s = \frac{(a+b+c)}{2} \]
\[ a = \text{R_cylin} - \text{R_roller} \]
\[ b = \text{Port_loca(r)} \]
\[ c = \text{R_roller} \]
Opening ratio 2

- $P_a$ and $P_b$ were determined on the basis of the position of the injection port location $(r, \theta)$.

- Increasing gradually from $P_a$ to $P_b$ by using the orifice correlation.

- Intermediate pressure determined by calculating the $R_{open2}$ that ratio of actual injection in $R_{open1}$.

Opening Ratio 2

$$R_{open2} = \frac{P_{inter} - P_a}{P_b - P_a}$$
SIMULATION VERIFICATION
Experimental setup
Simulation verification

- Cooling capacity, Power consumption, COP, Mass flow rate, Discharge temperature, Condensing pressure, Evaporating pressure
- Well matched with measured data within 10%
RESULTS AND DISCUSSION
Variables of injection port analysis

<table>
<thead>
<tr>
<th>Geometry of compressor</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Port location (r)</td>
<td>19.105mm</td>
</tr>
<tr>
<td>Port location (θ)</td>
<td>48.5°</td>
</tr>
<tr>
<td>Port size</td>
<td>1mm</td>
</tr>
</tbody>
</table>
Port location (r)

Discharge temperature decreased corresponding to the port location (r).
Port location (θ)

Influence of Opening ratio, mass flow rate and discharge temperature on port location (θ)

Discharge temperature decreased corresponding to the port location (θ).
Diameter of injection port

Influence of Opening ratio, mass flow rate and discharge temperature
port size

Decrease injection pressure → decrease $R_{open2}$
Mass flow rate of injection increased by increasing injection port diameter
Influence counter effect of increase diameter and decrease $R_{open2}$
The simulation model of the heat pump cycle with liquid injection technique was developed.

In the simulation logic, the convergences at each step were checked by mass and energy balances.

The simulation program was validated by comparing with the experimental data, and showed good agreement with the experimental data.

Injection mass flow rate increased with the increase of opening ratio according to the port location \((r), (\Theta)\)

The maximum flow rate was observed as the port size increased in the same EEV opening.
THANK YOU